

Research Article

Assessment of the threat status of bird species from Vietnam – Implementation of the One Plan Approach to conservation

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Abstract

Globally, 13% of the 11,188 bird species evaluated by the IUCN Red List face extinction risk, with nearly half experiencing population declines. Approximately 187 bird species have gone extinct or are suspected to be extinct since 1500. Vietnam has been well known for its extraordinary level of biodiversity, particularly its very rich bird fauna. However, although the country is home to more than 900 species, no efforts had been made to assess their conservation status to better protect them from extinction risks. For this reason, this study aimed to (1) provide a comprehensive list of bird species reported from Vietnam, incorporating IUCN and national threat statuses, i.e., the listings in the Vietnam's Red Data Book and two national legislations, alongside CITES; (2) identify avian richness hotspots and their coverage by the national protected area network; and (3) evaluate *ex situ* bird populations in zoos. Our analysis identified 803 native bird species, consisting of ten endemic and 17 near-endemic taxa, across 22 orders and 92 families, dominated by Passeriformes (453 species) and Charadriiformes (77). Of these, 741 were non-threatened, 43 threatened, and 19 non-evaluated or data deficient. A total of 61 species are listed in the Vietnam Red Data Book (2007; recently updated 2024 and now assessing 112 bird species): nine as Least Concern, 47 as threatened, and five as Data Deficient. In addition, 87 species are listed in the Appendices of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), while 138 species are included under national decrees, 26 in Decree No. 64/2019 and 138 (including the previous 26 species) in Decree No. 84/2021. Highest bird species richness was found in northern and central Vietnam, and the Mekong Delta is an important area for non-breeding species, but it had comparatively low protected area coverage. ZIMS data showed that 308 species are represented in zoo holdings, including 20 threatened and two threatened and endemic species. This updated avifaunal assessment underscores Vietnam's critical conservation needs, highlighting areas for improved protection, integration of expanded *ex situ* conservation efforts, and alignment of legislation with global conservation prioritizations.

Key words: Avian richness, CITES, *ex situ* conservation, Indochina, *in situ* conservation

Introduction

With over 11,000 species, birds (Aves) are the second most diverse class of terrestrial vertebrates, with their greatest diversity found in the tropics. They play vital ecological roles, such as seed dispersal, plant pollination, and pest control in sustainable agriculture. Since 1500, approximately 187 bird species have gone extinct or are suspected to be extinct (Lees et al. 2022). To date, 13% of the 11,188 bird species are assessed by the IUCN Red List as threatened, and nearly half are experiencing population declines (IUCN 2025; Lees et al. 2022). Key threats include habitat loss, overexploitation, and invasive species, with hunting and trapping being the most serious risks globally (Lees et al. 2022; BirdLife International 2023). In addition, about half of all extant bird species are utilized by humans, mainly as pets or for food (Lees et al. 2022).

In Asia, bird trapping and hunting is a pervasive issue with eight of the ten countries most affected globally located in the region. Vietnam ranks tenth in this regard (BirdLife International 2012). One of the primary drivers of bird declines and extinctions in Southeast Asia over the past two decades is trapping for the cage bird trade, a key component of the Asian songbird crisis (Sykes 2017; Leupen et al. 2022). Birds are often captured for their plumage or song with singing contests fuelling demand. This mostly illegal and unregulated trade takes place in traditional markets and increasingly moving to online platforms (Lees and Yuda 2022). The wildlife trade, along with the use of wildlife products, poses the largest threat to Vietnam's biodiversity (Sterling et al. 2006; WCS 2012, 2024; Nguyen and Dinh 2020).

Furthermore, Southeast Asia is a critical wintering region for migratory birds, particularly those from eastern Asia, many of which are in decline (Kirby et al. 2008). Vietnam is part of the migratory flyway East Asia – Australia (Melville 1997; Zalles and Bildstein 2000). These species undertake long migrations between breeding and non-breeding areas, facing numerous natural and human-induced threats along their flyways (Larison et al. 2021). Overexploitation is a significant threat to migratory birds, directly impacting populations in both breeding and non-breeding ranges. Additionally, the quality and availability of wintering habitats influence reproductive success during the breeding season, emphasizing the need for conservation efforts across their entire migratory range (Kirby et al. 2008; Larison et al. 2021).

The IUCN Conservation Planning Specialist Group (CPSG) introduced the One Plan Approach (OPA) to enhance species conservation by integrating different expertise as well as combining *in situ* and *ex situ* strategies (Byers et al. 2013; Schwartz et al. 2017). Protected areas (PAs) serve as a critical *in situ* tool to mitigating biodiversity loss in response to escalating human pressures (Stolton et al. 2015; De Alban et al. 2021; Brodie et al. 2023). According to the World Database on Protected Areas (WDPA), Vietnam's PA network encompasses 175 sites, covering roughly 25,000 km² or 7.58% of the country's area (UNEP-WCMC & IUCN 2022). On the other hand, zoos and aquariums can also effectively support *in situ* initiatives and can temporarily act as safe havens ("modern ark" principle) for highly threatened species. For instance, they can improve offspring survival, as demonstrated in reptiles (Gibbons 1987), and provide surplus individuals for potential reintroduction (Ziegler 2015, 2023). Conservation-focused zoos are recognized as key models, serving as hubs

within broader conservation networks (Spooner et al. 2023; Ziegler 2023). Furthermore, international and national legislations, such as the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) and its national implementations, which regulate the international wildlife trade, are also powerful tools for species protection (CITES 2023).

Vietnam, an important part of the Indo-Burma global hotspot, has been renowned for its exceptional species richness, high endemism, and diverse ecosystems, ranking 15th globally among the world's most biodiverse countries (Worldstats 2025). In total, it hosts over 10,500 terrestrial animal species, including more than 900 birds, and is home to some of Asia's most threatened bird species, such as the endemic, and probably functionally extinct in the wild, Edwards's Pheasant (*Lophura edwardsi*) (Duwe et al. 2022). However, to date, the taxonomy and conservation status of the majority of the country's avifauna has not been evaluated, impeding their conservation efforts. Recent field guides (Craik and Le 2018; Le et al. 2021) provide valuable data on bird distributions in Vietnam but often differ in their taxonomic treatments. For example, Craik and Le (2018) follow the Clements Checklist of Birds of the World, whereas Le et al. (2021) follow the IOC.

Frequent taxonomic revisions on individual bird families or genera further complicate species listings and may alter the count of endemic species. To fill the gaps, the objectives of this study are: (1) to provide a comprehensive list of bird species reported from Vietnam, incorporating IUCN and national threat statuses, as specified in the recently updated Vietnam Red Data Book and two national legislations, alongside CITES classification; (2) to identify hotspots for avian species richness within the country and their PA coverage; and (3) to analyse the status of *ex situ* populations of Vietnamese bird species in zoos worldwide.

Methods

Data collection and preparation

To compile an updated list of bird species native to Vietnam, we used the checklists of Le et al. (2021), BirdLife International (2023), Avibase (2023) and IUCN Red List (IUCN 2025). If the checklists provided contradictory or uncertain accounts, additional references on the respective species were taken into consideration (e.g., Robson 2008; Craik and Le 2018). Taxonomically, we followed the IOC World Bird List (Gill et al. 2023) but in the cases of *Oroanassa magnifica*, *Himalayapsitta finschii*, *H. roseata*, *Palaeornis eupatria*, *Suthora webbiana*, *S. alphonsiana*, *S. atosuperciliaris*, *Paradoxornis bakeri*, *P. gularis*, *P. margaritae*, *Ichthyophaga ichthyaetus*, *I. humilis*, and *Suthora davidiana*, BirdLife International (2023) provided more updated information. Furthermore, birds endemic and near-endemic to Vietnam were determined. A species was considered near-endemic if it is endemic to Indochina and native to Vietnam and a neighboring Indochinese country (Craik and Le 2018). The distributional status of the Vietnamese birds was categorized into passage migrant, vagrant, introduced, extinct, wintering, resident, and breeding visitor (Le et al. 2021; BirdLife International 2023). In cases of contradictory data, the expert opinion was consulted (HM Le pers. comm.). Species identified as passage migrant, vagrant, introduced and extinct were excluded from further analyses.

The threat status and population trend were obtained from the IUCN Red List (IUCN 2025) between June 20 to June 25, 2023. Species assessed as Least Concern (LC) and Near Threatened (NT) were regarded as non-threatened, while species evaluated as Vulnerable (VU), Endangered (EN) and Critically Endangered (CR) were considered threatened. For twelve species, as their taxonomy in the IUCN Red List was outdated, only the distribution of Vietnamese populations was analyzed. They include *Dryobates cathpharius* (previously known as *D. pernyi*), *Garrulus glandarius* (*G. leucotis*), *Urocissa whiteheadi* (*U. xanthomelana*), *Picus canus* (*P. guerini*), *Eurylaimus javanicus* (*E. harterti*), *Actinodura ramsayi* (*A. radcliffei*), *Ianthocincla cineracea* (*I. cinereiceps*), *Aethopyga christinae* (*A. latouchii*), *Coracina macei* (*C. javensis*), *Hirundo tahitica* (*H. javanica*), *Psilopogon duvaucelli* (*P. cyanotis*) and *Surniculus lugubris* (*S. dicruroides*).

To enhance the protection of not only rare and threatened but also traded bird species, we included information from the appendices of CITES. For this purpose, the website Species+ was accessed between June 20 and June 25, 2023, which provides information on all CITES-related species (Species+ 2023). Additionally, we cross-validated the data available from the last version of the Vietnam Red Data Book (VRDB; Dang et al. 2007) and two national decrees, which are issued to protect endangered, rare, and prioritized species. While the VRDB (Dang et al. 2007; Nguyen 2024) provides information on nationally threatened and rare species, Decree No. 64/2019 lists species with top priority for conservation, and Decree No. 84/2021 features rare wild fauna and flora threatened by trade and is the national implementation of the CITES regulations.

Richness analyses

To identify national avian hotspots and to assess the PA coverage, a species richness analysis was performed. Spatial data containing the species distributions were obtained as polygon shapefiles from the IUCN Red List (IUCN 2025). We excluded a total of 119 species, whose shapefiles could not be obtained due to missing or damaged shapefiles, and distribution data were unavailable, from the richness analysis. The assessment of avian richness in Vietnam was conducted using R (v4.0.3; R Core Team 2020) with the aid of the packages *extractr* (Baston 2022), *raster* (Hijmans 2021), *shapefile* (Stabler 2013), *terra* (Hijmans 2023), and *rredlist* (Gearty and Chamberlain 2022). For each species, a presence-absence raster map with a resolution of 30 arc seconds (~930 * 900 m) was generated based on IUCN shapefiles and gridded habitat information (Jung et al. 2020) based on habitat classes provided in the IUCN species accounts. The latter was extracted using the *rredlist* package for R. These data were then used to produce species richness maps for breeding, non-breeding, resident, threatened breeding, threatened non-breeding, and threatened resident species occurring in Vietnam. Additionally, we calculated the number of all, breeding, non-breeding and resident Vietnamese bird species in each habitat category (measured in 100 * 100 m grid cells) and the area of each habitat type relative to Vietnam's surface area.

Polygon shapefiles representing Vietnam's PAs were retrieved from the World Database on Protected Areas (WDPA) under the Protected Planet Initiative and cross-referenced with nationally recognized areas. To determine the

potential presence of each bird species within these PAs, the species' presence-absence maps were overlaid on the PA layers. A species was considered potentially present if at least one grid cell within a PA indicated occurrence.

Zoo diversity analysis

The Zoological Information Management Software (ZIMS 2023) was accessed between June 16 and June 26, 2023 to search for Vietnamese birds held in zoos globally. Data collected included *ex situ* population size, sex, breeding success over the past twelve months, and the hosting institutions. The analysis was only conducted at the species level. Additionally, the Shannon diversity index (H) was calculated for each institution using the R packages BiodiversityR (Kindt & Coe 2005) and vegan (Oksanen et al. 2024). Moreover, the "zootierliste" (ZTL) was accessed at the same time period. ZTL is an online database that provides information on the current and former keepings of vertebrate populations in zoos and other public animal husbandry facilities (Zootierliste 2023). However, ZTL only stores data on whether a species is/was kept but does not record any of the other details as available from ZIMS.

Results

Avian richness in Vietnam

A total of 803 bird species classified in 22 orders and 92 families was identified as native to Vietnam, of which Passeriformes (453 species, 56.4%) and Charadriiformes (77, 9.6%) represent the two most species-rich groups (Suppl. materials 1, 2: tables S1, S2). On the other hand, Muscicapidae (59), Leiothrichidae (41), Phylloscopidae (29; all Passeriformes), Scolopacidae (35; Charadriiformes) and Accipitridae (31; Accipitriformes) were the most diverse families. Among them, 741 species were classified in the IUCN Red List as non-threatened (LC 697, 88.8%, NT 44, 5.6%), 43 as threatened (VU 21, 2.6%; EN 11, 1.4%; CR 11, 1.4%), and 19 as non-evaluated (NA 18, 2.2%, DD 1, 0.1%; Fig. 1, Suppl. materials 1, 2: tables S1, S2). The highest proportion of the 43 threatened species belonged to Passeriformes (twelve, 27.9%) followed by Charadriiformes (six, 14.0%).

Ten species (1.2%) were endemic to Vietnam and 17 species (2.1%) were near-endemic (Table 1). Of the endemic species, three were LC, four EN and one was CR (Fig. 1). The two endemic species, the Dalat Bush warbler (*Locustella idonea*) and the Annam Prinia (*Prinia rocki*), were non-evaluated by the IUCN. For the near-endemic species, eight were LC, five NT, two each VU and CR (Fig. 1). Most (near-)endemic species belonged to Passeriformes (19, 70.4%), followed by Galliformes (four, 14.8%), Piciformes (three, 11.1%), and Pelecaniformes (one, 3.7%; Fig. 1). Nearly half (359, 45.8%) of the Vietnamese bird species showed declining populations. For 304 species, population trends were stable, 47 species had increasing populations, and for the remaining 75 species, the trends were unknown (Fig. 1).

The VRDB (Dang et al. 2007) comprised 61 species, nine were classified as Lower Risk (LR, which is synonymously used to the IUCN Red List category LC), 47 as threatened (VU 24, EN 15, CR 8), and five as DD (Suppl. material 2: table S3). Within the threatened category, four species were listed as threatened

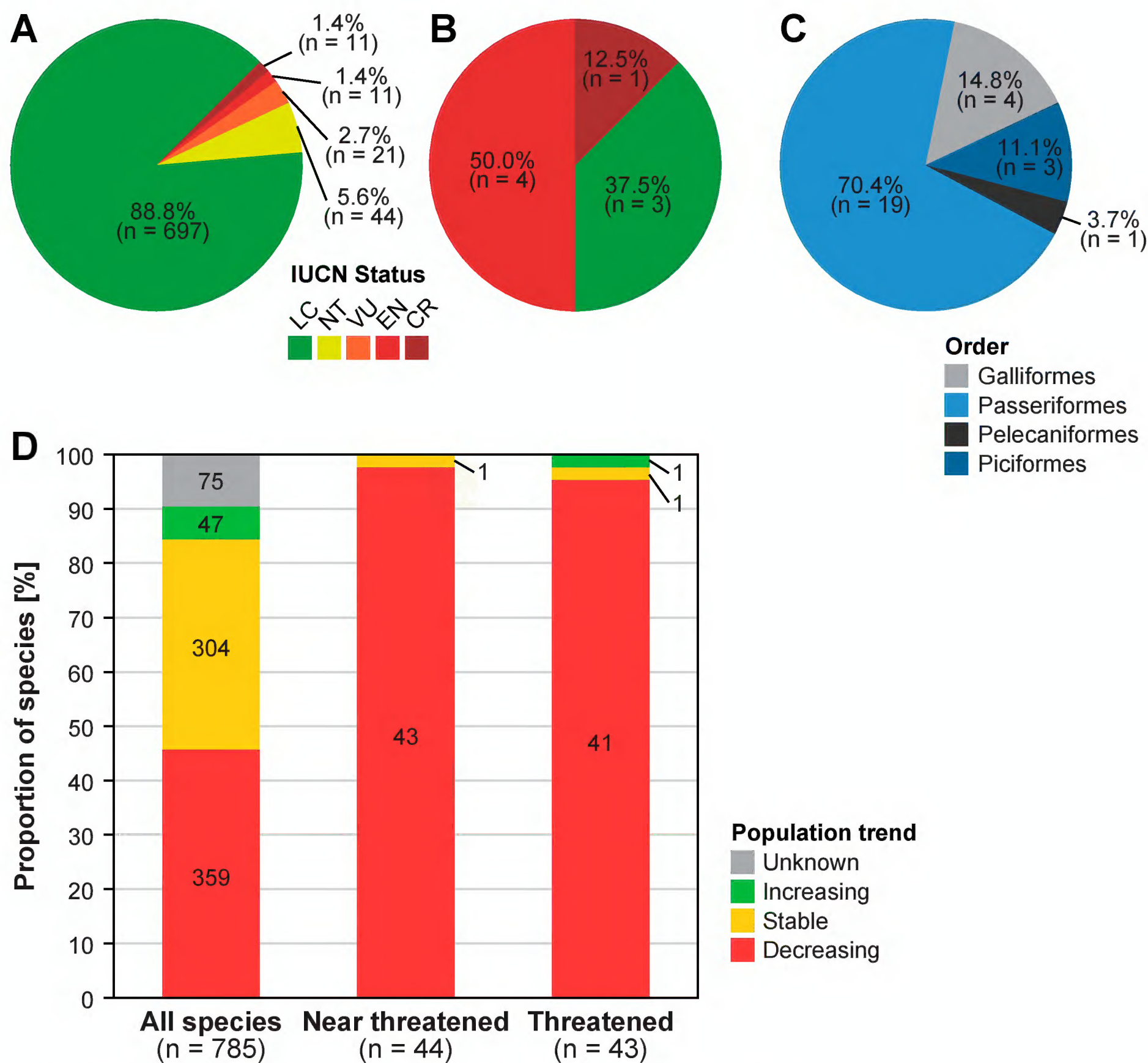


Figure 1. A. Vietnamese bird species listed in the IUCN Red List (n = 785) for which a status was available, the single DD species (0.1%) is not presented; B. Endemic bird species (n = 8) listed in the IUCN Red List for which a status was available; C. Birds within both endemism categories (n=27), separated by order; D. Population trends by categories according to the IUCN Red List for all species combined and for near threatened and threatened species.

(VU 1, CR 3) and one as NT according to the IUCN Red List. For the remaining birds, the statuses of 21 species in the VRDB were identical to those in the IUCN Red List, while they differed for the other 35 species. Of these, 26 species were assessed with a higher threat status in the VRDB than in the IUCN Red List. However, nine species were classified as more threatened in the IUCN Red List, including the two threatened endemic species, the Vietnamese Pheasant (*Lophura edwardsi*) and the Golden-winged Laughingthrush (*Trochalopteron ngoclinhense*). Five of the ten endemic species and 31 of the 43 threatened species according to the IUCN Red List were listed in the VRDB.

In total 10.8% (87) of the Vietnamese bird species were covered by one of three appendices under CITES: nine (including seven threatened) species were listed in Appendix I, 75 (including six threatened) species in Appendix II and three species in Appendix III (Suppl. material 2: tables S3, S4). In some cases, whole

Table 1. Bird species in Vietnam within an endemism category (E = endemic; NE = near-endemic), the IUCN Red List status, population trend (Inc = increasing, Dec = decreasing, S = stable, U = unknown, NA = not available) and distribution according to Le et al. (2021) and IUCN (2022); threatened species (VU, EN, CR) are highlighted shaded; * = last record in 2009 (Eames and Mahood, 2017).

Species	Endemism	IUCN	Trend	Distribution
Family Cisticolidae				
<i>Prinia rocki</i>	E	NA	NA	Central and South Central Vietnam
Family Fringillidae				
<i>Chloris monguilloti</i>	E	LC	U	South Central, Da Lat Plateau
Family Leiothrichidae				
<i>Actinodura sodangorum</i>	NE	NT	S	Laos, Vietnam
<i>Cutia legalleni</i>	NE	NT	Dec	Laos, Vietnam
<i>Garrulax annamensis</i>	E	LC	S	South Central, Da Lat Plateau
<i>Garrulax milleti</i>	NE	LC	Dec	Laos, Vietnam
<i>Ianthocincla konkakhensis</i>	NE	VU	S	Laos, Vietnam
<i>Laniellus langbianis</i>	E	EN	Dec	South Central, Da Lat Plateau
<i>Pterorhinus vassali</i>	NE	LC	S	Cambodia, Laos, Vietnam
<i>Trochalopteron ngoclinhense</i>	E	EN	Dec	Central Truong Son, Kon Tum Plateau
<i>Trochalopteron yersini</i>	E	EN	Dec	South Central, Da Lat Plateau
Family Locustellidae				
<i>Locustella idonea</i>	E	NA	NA	South Central
Family Megalaimidae				
<i>Psilopogon annamensis</i>	NE	LC	Dec	Laos, Vietnam
<i>Psilopogon auricularis</i>	NE	LC	S	Laos, Vietnam
<i>Psilopogon lagrandieri</i>	NE	LC	Dec	Cambodia, Laos, Vietnam
Family Paradoxornithidae				
<i>Fulvetta danisi</i>	NE	LC	Inc	Laos, Vietnam
<i>Paradoxornis margaritae</i>	NE	VU	Dec	Cambodia, Vietnam
Family Pellorneidae				
<i>Napothera danjoui</i>	NE	NT	Dec	Laos, Vietnam
<i>Napothera pasquieri</i>	E	EN	Dec	Northwestern Vietnam, Hoang Lien Mountains
<i>Schoeniparus klossi</i>	E	LC	S	South Central, Southern Lowlands, Da Lat Plateau and Kon Tum Plateau
Family Phasianidae				
<i>Arborophila davidi</i>	NE	NT	Dec	Cambodia, Vietnam
<i>Lophura edwardsi</i>	E	CR	Dec	Central Vietnam
<i>Polyplectron germaini</i>	NE	NT	Dec	Cambodia, Vietnam
<i>Rheinardia ocellata</i>	NE	CR	Dec	Laos, Vietnam
Family Threskiornithidae				
<i>Pseudibis gigantea</i>	NE	CR	Dec	Cambodia, Laos, Vietnam
Family Timaliidae				
<i>Mixornis kelleyi</i>	NE	LC	Dec	Cambodia, Laos, Vietnam
<i>Stachyris herberti</i>	NE	LC	Dec	Laos, Vietnam

orders were included in CITES, such as Accipitriformes, Falconiformes, Strigiformes and Psittaciformes. One of the ten endemic species, *Lophura edwardsi* (CR), was included in Appendix I. Among the near-endemic species, the Vietnamese Crested Argus (*Rheinardia ocellata*) (CR) was placed in Appendix I and the Germain's Peacock-Pheasant (*Polyplectron germaini*) (NT) in Appendix II.

Similar, the national Decree No. 84/2021 differentiated between two appendices. In total, 17.2% (138) of the bird species of Vietnam were covered, 33 of them in Group IB and 105 in Group IIB (Suppl. material 2: tables S3, S4). All nine species listed in CITES Appendix I were also present in Group IB under the national legislation. An additional 65 species was included in both CITES Appendix II and Group IIB at national level. Six species were listed in CITES but not yet included in Decree No. 84/2021, including the three species in Appendix III, i.e., the White-rumped Shama (*Copsychus malabaricus*) (LC), the Common Crane (*Grus grus*) (LC), and the Slender-billed Vulture (*Gyps tenuirostris*) (CR, but possibly extinct in Vietnam). Regarding the latter, Decree No. 84/2021 contained the excluded species *Gyps indicus*, which encompassed *G. tenuirostris* before it was recognized as a full species. Furthermore, seven species were listed in Group IB in Decree No. 84/2021, but in CITES Appendix II. Another 57 species were placed in Decree No. 84/2021, but not in CITES. Of the threatened species, 27 were included in Decree No. 84/2021. In addition, the decree also consists of five endemic species.

Decree No. 64/2019 included 26 species, all listed in Group IB of Decree No. 84/2021 (Suppl. material 2: tables S3, S4). Only *Lophura edwardsi* and *Trochaloxyeron ngoclinhense* were endemic species. The threatened endemic species *Napothera pasquieri* was not covered by CITES, nor by any of the decrees, and absent from the VRDB. Additionally, all species except the Giant Ibis (*Pseudibis gigantea*) (DD) and the Austen's Brown Hornbill (*Anorrhinus austeni*) (NA) were considered threatened by the VRDB. But the Tickell's Brown Hornbill (*Anorrhinus tickelli*) was listed there, before its taxonomy changed according to IOC World Bird List.

The richness analysis for the breeding species showed the highest richness in northern Vietnam reaching a maximum of eleven species per grid cell and declining towards central and southern Vietnam. For threatened breeding species, the only distributional range was in northwestern Vietnam with a maximum of only one species per grid cell. Considering the number of breeding species per PA, most PAs with high species richness could be found in the North, reaching a maximum of 17 species (Fig. 2A, D, G). The richness of non-breeding species was moderate to high across the country, with the greatest number of 40 species per grid cell occurring in the northwestern upland along the northern Annamite Range (Truong Son) and in southern Vietnam. The number of threatened non-breeding species rose to the highest level (max. five species/grid cell) in the Mekong Delta in southern Vietnam and decreased towards the North. In PAs, the richness of non-breeding species was moderate to high across the entire country. However, fewer species were found in the southern Truong Son Range. Maxima were reached in several PAs in the North and one in the South with 84 species per PA (Fig. 2B, E, H).

Considering resident species, moderate to high richness was observed in northern and central Vietnam. Maxima of up to 221 species were found in the northwestern mountainous regions, along the northern and central Truong Son Range, and at their southern end. The distribution of threatened resident species was similar, but with maxima of up to eight species in the northern and central Annamite Range, as well as around the Da Lat Plateau at the southern end

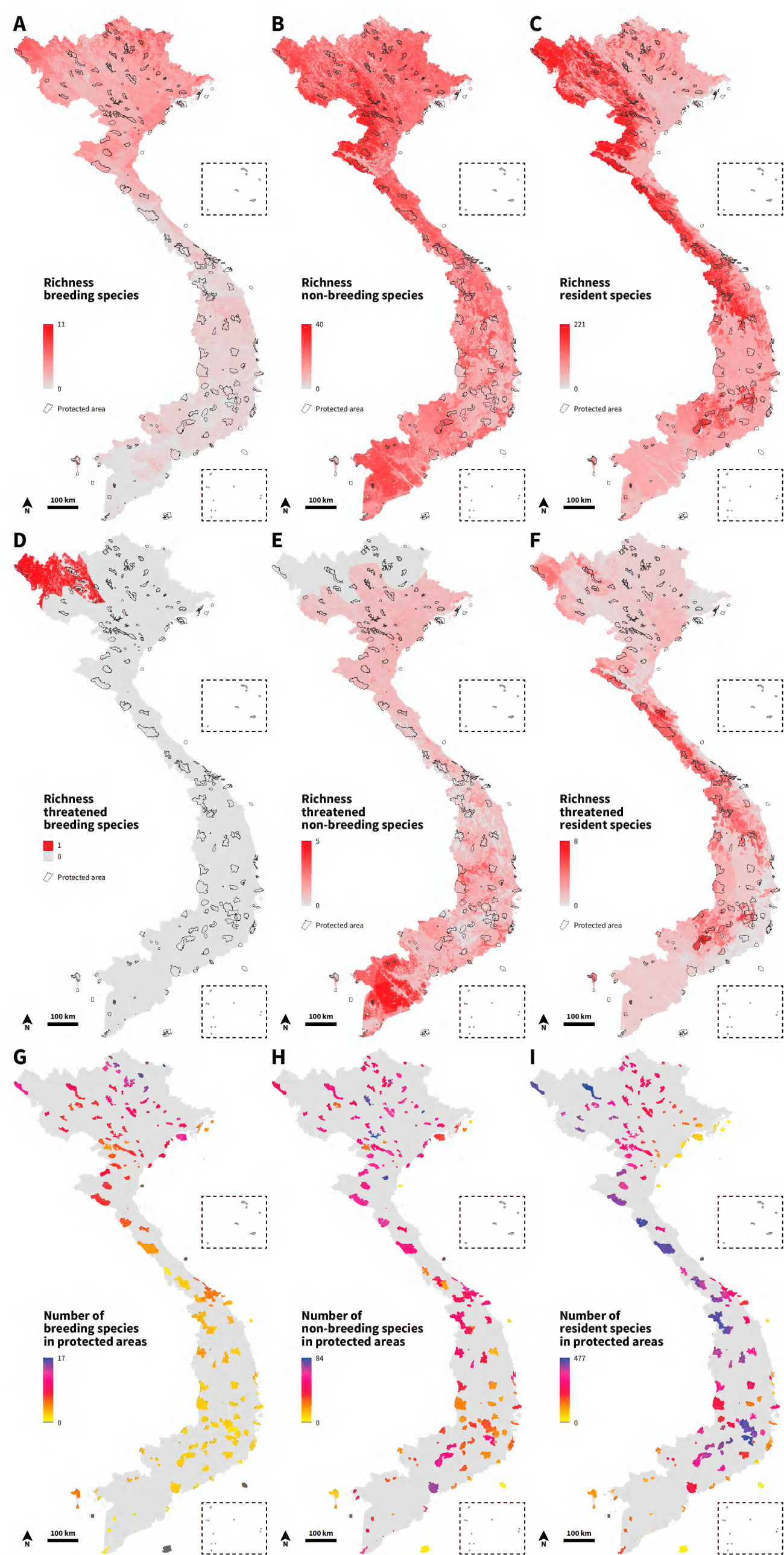


Figure 2. Richness analysis for Vietnamese breeding species (A), non-breeding species (B), resident species (C), threatened breeding species (D), threatened non-breeding species (E), threatened resident species (F); and the species number of breeding species (G), non-breeding species (H) and resident species (I) occurring in protected areas in Vietnam.

of Truong Son Range. The number of resident bird species in PAs also attained the highest level (up to 477 species per PA) in the northwestern mountainous regions, along the northern and central Truong Son Range, and at their Southern end (Fig. 2C, F, I). Additionally, eight of ten endemic species occur in at least two PAs (Table 2). In the PAs of Chu Yang Sin (Dak Lak Province), Rung Thong Da Lat, and Bidoup-Nui Ba (Lam Dong Province), which are located close to each other, five endemic species, *Chloris monguilloti*, *Garrulax annamensis*, *Laniellus langbianis*, *Trochaloxyeron yersini* and *Schoeniparus klossi*, were found.

In Vietnam, bird species were found within nine habitat categories and 27 sub-categories according to IUCN Red List, including different types of forest (category 1), savanna (2), shrubland (3), grassland (4), inland wetlands (5), rocky areas (6), marine neritic (9), marine intertidal (12) and artificial terrestrial (14; Table 3). Of these habitat categories, subtropical/tropical moist lowland forest inhabited the largest relative area with 22.74% (total number of species: 200), followed by plantation (16.30%, total number of species: two), arable land (14.66%, five species), subtropical/tropical moist montane forest (8.77%, 165 species) and subtropical/tropical dry forest (8.65%, 25 species). The habitat categories with the smallest relative area were seasonal/intermittent/irregular streams/rivers/creeks (two species), subtropical/tropical high altitude grassland (three species), seasonally/intermittent freshwater marshes/pools (one species), rocky areas (13 species; each habitat category with a relative area of <0.01%), seasonal/intermittent freshwater lakes (one species), mangrove submerged roots (one species) and pastureland (one species; each category with a relative area of 0.01%).

The four most species-rich habitats for Vietnamese birds were forests and inland wetlands. Of the sub-categories, subtropical/tropical moist lowland forest was the most species-rich habitat in total, for breeding, non-breeding and resident birds (total: 200, breeding: 24, non-breeding: 31, resident: 145) with a relative area of 22.74% (Table 3). Subtropical/tropical moist montane forest harbored the second-most bird species in total but also the second-most resident, and the third-most breeding and non-breeding species (total: 165, breeding: 15, non-breeding: 11, resident: 139, relative area: 8.77%). The third-most species in total were present at permanent rivers/streams, including the fourth-most breeding, non-breeding, and third-most resident bird species (total: 40, breeding: 13, non-breeding: 9, resident: 18, relative area: 0.16%). Permanent freshwater lakes were habitat for the fourth-most avian species in total, but also for the second-most breeding and non-breeding species (total: 33, breeding: 16, non-breeding: 13, resident: 4, relative area: 0.14%). The fifth-most species in total were found in subtropical/tropical dry forest, which inhabited the third-most resident species (total: 25, breeding: 3, non-breeding: 4, resident: 18, relative area: 8.65%). Additionally, rocky areas were important habitats for breeding species (seven, relative area: <0.01%), whereas several non-breeding species were found in dry savanna (six, relative area: 4.43%), and a further ten species of resident birds occupied subtropical/tropical high altitude shrubland (relative area: 0.82%).

Of the 803 bird species of Vietnam, 308 species (38.4%) were held in zoos. Thereby, 211 species were listed in both ZIMS and ZTL, another 79 species were listed in ZIMS only and 18 species were exclusively in ZTL (Suppl. material 2: tables S5, S6). Of the 290 species listed in ZIMS, 20 out of 43 (46.5%) threatened bird species (VU 9, EN 4, CR 7; Table 4) and 24 out of 44 (54.5%) NT species were present in zoos. Of the 233 Vietnamese bird species listed

Table 2. Endemic species in Vietnam, their IUCN Red List threat status and number of inhabited protected areas.

species	IUCN	number of PAs
<i>Chloris monguilloti</i>	LC	9
<i>Garrulax annamensis</i>	LC	9
<i>Laniellus langbianis</i>	EN	3
<i>Lophura edwardsi</i>	CR	12
<i>Napothera pasquieri</i>	EN	3
<i>Schoeniparus klossi</i>	LC	8
<i>Trochalopteron ngoclinhense</i>	EN	2
<i>Trochalopteron yersini</i>	EN	4

Table 3. The number of all (total), breeding, non-breeding and resident Vietnamese birds in the habitat type according to IUCN categories (habitat), the number of 100 * 100 m grid cells in Vietnam (n.cells) and the habitat area relative to Vietnam’s surface area (area [%]).

habitat	n.cells	area [%]	breeding	non-breeding	resident	total
1.5 subtropical/tropical dry forest	2989421	8.65	3	4	18	25
1.6 subtropical/tropical moist lowland forest	7861410	22.74	24	31	145	200
1.7 subtropical/tropical vegetation above high tide level	96580	0.28	2	2	6	10
1.8 subtropical/tropical swamp forest	61910	0.18	1		5	6
1.9 subtropical/tropical moist montane forest	3032759	8.77	15	11	139	165
2.1 dry savanna	1530082	4.43	2	6	5	13
3.5 subtropical/tropical dry shrubland	246216	0.71	2	2	8	12
3.6 subtropical/tropical moist shrubland	225274	0.65	1	1	6	8
3.7 subtropical/tropical high altitude shrubland	285093	0.82	5		10	15
4.5 subtropical/tropical dry grassland	22102	0.06	2	2	8	12
4.6 subtropical/tropical seasonally wet/flooded grassland	9020	0.03	2	3	7	12
4.7 subtropical/tropical high altitude grassland	22	<0.01	2		1	3
5.1 permanent rivers/streams	56866	0.16	13	9	18	40
5.2 seasonal/intermittent/irregular streams/rivers/creeks	1060	<0.01		1	1	2
5.5 permanent freshwater lakes	49560	0.14	16	13	4	33
5.6 seasonal/intermittent freshwater lakes	3952	0.01		1		1
5.7 permanent freshwater marshes/pools	279479	0.81	5	5	6	16
5.8 seasonal/intermittent freshwater marshes/pools	434	<0.01			1	1
6.0 rocky areas (e.g. inland cliffs, mountain peaks)	72	<0.01	7	3	3	13
9.9 seagrass (submerged)	20408	0.06	5	5	3	13
12.6 tidepools	5369	0.02		1	1	2
12.7 mangrove submerged roots	2591	0.01			1	1
14.1 arable land	5068978	14.66	1	2	2	5
14.2 pastureland	211788	0.01			1	1
14.3 plantation	5634779	16.30			2	2
14.4 rural gardens	2840354	8.22			1	1
14.5 urban areas	1510942	4.37			1	1

Vietnamese birds in zoos across ZIMS-regions

Table 4. Threatened Vietnamese bird species held in zoos according to ZIMS (n = 20). *: endemic, **: near-endemic.

species	IUCN	number of zoos (regions)	individuals	hatch	breeding institutions
<i>Aceros nipalensis</i>	VU	2 (1)	2	-	-
<i>Asarcornis scutulata</i>	EN	37 (3)	158	25	4
<i>Aythya baeri</i>	CR	56 (3)	350	83	11
<i>Aythya ferina</i>	VU	46 (3)	330	16	2
<i>Buceros bicornis</i>	VU	51 (5)	182	-	-
<i>Clanga clanga</i>	VU	7 (2)	19	-	-
<i>Columba punicea</i>	VU	2 (2)	3	-	-
<i>Grus antigone</i>	VU	59 (3)	227	26	4
<i>Gyps bengalensis</i>	CR	3 (2)	4	-	-
<i>Houbaropsis bengalensis</i>	CR	1 (1)	10	2	1
<i>Leptoptilos javanicus</i>	VU	12 (3)	104	2	1
<i>Lophura edwardsi</i> *	CR	123 (3)	452	74	23
<i>Mulleripicus pulverulentus</i>	VU	1 (1)	1	-	-
<i>Pavo muticus</i>	EN	40 (6)	161	12	3
<i>Platalea minor</i>	EN	10 (2)	120	15	4
<i>Pseudibis davisoni</i>	CR	1 (1)	9	2	1
<i>Pseudibis gigantea</i> **	CR	1 (1)	3	-	-
<i>Rheinardia ocellata</i> **	CR	2 (1)	43	1	1
<i>Rhyticeros undulatus</i>	VU	39 (4)	144	2	1
<i>Trochalopteron yersini</i> *	EN	1 (1)	2	-	-

in ZTL, 217 species were non-threatened (LC 197, NT 20), 14 threatened (VU 8, EN 3, CR 3), and two NE according to IUCN Red List. Among the 18 species exclusively listed in ZTL, 17 species were non-threatened (LC) and one species was CR, namely the Spoon-billed Sandpiper (*Calidris pygmaea*) (Table 4), which was held at Slimbridge (Wildfowl and Wetlands Trust), UK.

The three largest *ex situ* populations among the threatened species belonged to the Vietnamese Pheasant (*Lophura edwardsi*) (452 across 123 zoos), the Baer’s Pochard (*Aythya baeri*) (350 across 56 zoos) and the Common Pochard (*Aythya ferina*) (330 across 46 zoos), while the *ex situ* populations of half of the threatened species (10) consisted of fewer than 50 individuals (Table 4). Overall, 49 out of the 290 bird species (16.9%) kept in zoos were represented by only one individual each in a zoo, including the threatened species, the Great Slaty Woodpecker (*Mulleripicus pulverulentus*) (VU) and the Rufous-necked hornbill (*Aceros nipalensis*). Of the 290 species listed in ZIMS, 110 (37.9%) reproduced within the last twelve months. Twelve of them were threatened.

Of the ten endemic bird species, two threatened taxa (EN 1, CR 1) were represented in zoos. However, while *Lophura edwardsi* was kept by the third highest number of institutions (123) with the largest population, *Trochalopteron yersini* was held by one institution with only one male and one female and without successful breeding. Four of the 17 near-endemic species were present in zoos, comprising the two threatened (CR 2) species *Pseudibis gigantea* and *Rheinardia ocellata*. Only the latter had breeding success within the last twelve months. The other two near-endemic species, the Black-hooded Laughingthrush (*Garrulax milleti*) (LC) and the Germain’s Peacock-Pheasant (*Polyplectron germaini*) (NT), were only kept with one and 17 individuals respectively. The latter, distributed across ten zoos with two of them having had breeding success. However, six of the ten zoos only kept one individual each.

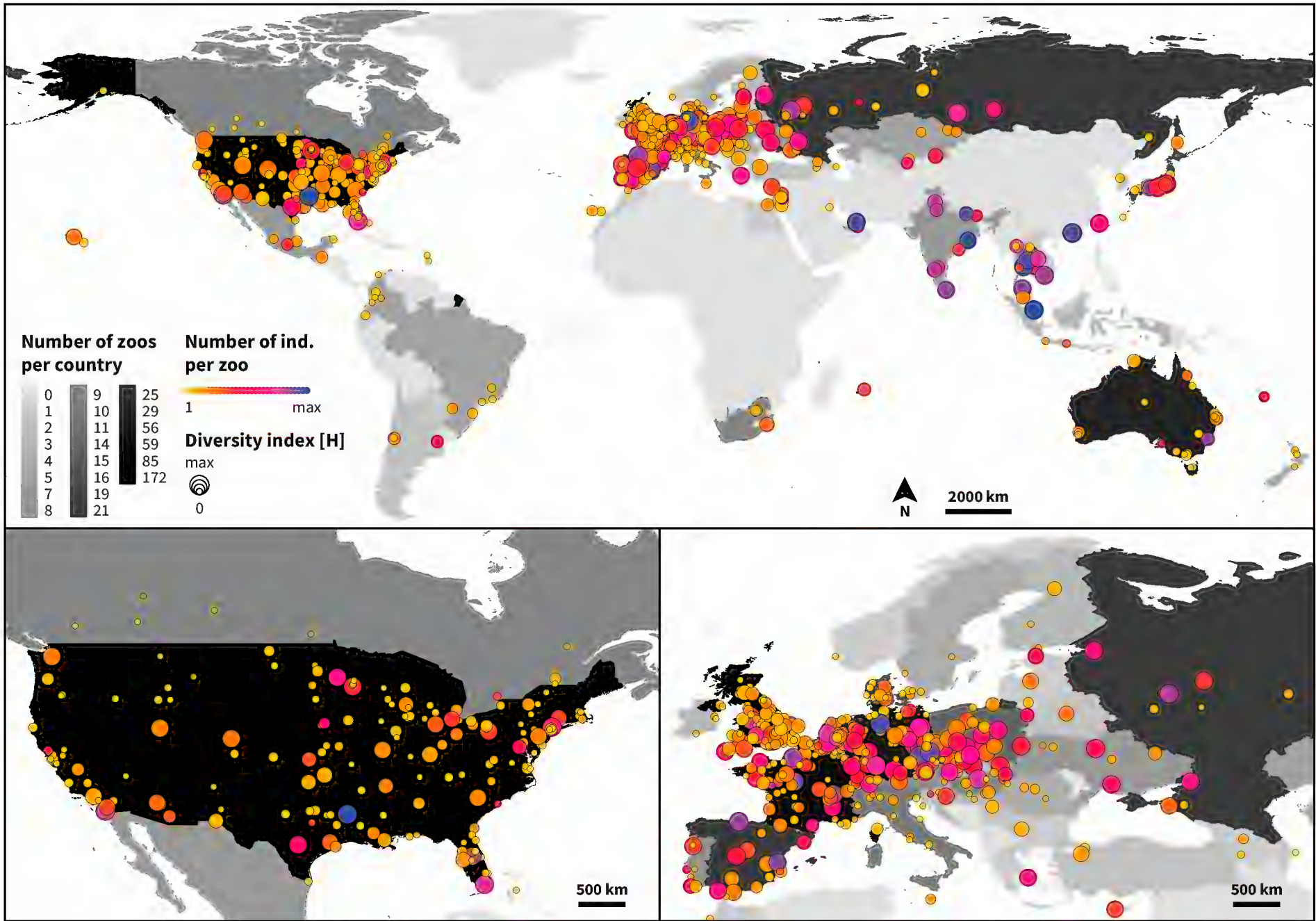


Figure 3. Avian diversity across ZIMS-regions measured by the number of zoos per country, the number of individuals per zoo, and the Shannon diversity index (H).

Most Vietnamese species were held in Asia (236) followed by Europe (185) and North America (119). The lowest numbers of species were held in Oceanian (33), African (30) and South American (25) zoos. According to ZIMS, a total of 750 zoological institutions worldwide kept at least one Vietnamese bird species. Furthermore, 116 zoos held at least two and 48 zoos at least three threatened species (Suppl. material 2: table S7). Singapore Zoo kept the most threatened species (eleven), followed by Miami Zoo, and Weltvogelpark Walsrode, which each kept seven threatened species. Most (near-)endemic species were kept at Saigon Zoo & Botanical Gardens (i.e., *Lophura edwardsi*, *Rheinardia ocellata*, and *Polyplectron germaini*). Greatest densities of zoos keeping Vietnamese bird species were found in Europe and North America. Many zoos with a high Vietnamese bird diversity and number of individuals per zoo were located in Asia (Fig. 3).

Discussion

Avian richness in Vietnam and its threats

We identified 803 bird species native to Vietnam, including ten endemic (1.2%) and 17 near-endemic species (2.1%). Duwe et al. (2022) mentioned more than 900 bird species occurring in Vietnam and according to eBIRD 868 bird species were listed for the country. This discrepancy can be explained by following different taxonomy and further we cannot exclude that different vagrant species

are listed as well. Compared to other vertebrate groups such as amphibians (95 endemic of 275 species, 34.5%; Krzikowski et al. 2022), reptiles (159 of 484 species, 32.9%; Stenger et al. 2023) and mammals (36 of 329 species, 11%; Höffner et al. 2024), the bird species richness is much higher but the rate of endemism is the lowest. The high species richness might be attributable to multiple reasons, i.e., the region's intricate geological and climatic history, Vietnam's extensive latitudinal span (23° to 8°30"N) crossing a subtropical to tropical transition zone, a high diversity of ecosystems, and its diverse terrain characterized by hills and mountains (Sterling and Hurley 2005). And both the high diversity and the low number of (near-)endemic species might be explained by birds being good dispersers that are less restricted by geographical barriers.

The majority (741 species, 94.4%) of bird species native to Vietnam is non-threatened according to the IUCN Red List. However, up to 45.8% of the Vietnamese bird species showed declining populations. Overall, the main threats to bird populations across Vietnam are habitat loss, hunting and trapping, and invasive species (Lees et al. 2022; BirdLife International 2023). The trapping for the cage bird trade, driven by deeply ingrained cultural traditions of keeping birds for their songs, striking plumage, or perceived rarity, has been identified as a key factor for the decline and extinction of many bird species across Southeast Asia in the 21st century (Capotosto and Shepherd 2015; Eaton et al. 2015; Sykes 2017). Particularly, (near-)endemic species are vulnerable to the impacts of climate and habitat changes due to their restricted range and special environmental conditions (Shipley and McGuire 2022).

Our richness maps showed that northern and central Vietnam serve as very important areas for the Vietnamese avifauna, whereas the Mekong Delta in the South is essential for non-breeding species. However, in the South, the PA coverage with regard to bird distribution was relatively low. Therefore, several key areas for birds should be protected including the northeastern region, south-central, southern coastal zone, and Mekong Delta for migratory (particularly for waterbirds) and wintering species. Furthermore, the northwestern region, northern and central Truong Son, and the Central Highlands as well as southern Vietnam are important key areas for breeding species and passerine migratory species, especially the Central Highlands, where most of the endemic species had been recorded (Le et al. 2021). Particularly, forest and inland wetland habitats were highly specious. The habitat sub-categories subtropical/tropical moist lowland forest (species: 200, relative area: 22.74%), subtropical/tropical moist montane forest (species: 165, relative area: 8.77%), permanent rivers/streams (species: 40, relative area: 0.16%), permanent freshwater lakes (species: 33, relative area: 0.14%) and subtropical/tropical dry forest (species: 25, relative area: 8.65%) had the highest avian species richness (Table 3). However, it must be mentioned that the IUCN categorizations as well as the distribution shapefiles, which were used to create the maps, are biased, and the real distribution of a species and its habitat use might differ slightly in some cases.

In situ conservation actions for Vietnamese birds

Species and nature conservation actions can offer novel opportunities for local communities. Sites with high avian richness might be an attraction for birding tourism, which holds significant potential for enhancing the financial and environmental

well-being of locals, raising awareness about the importance of biodiversity, and fostering local and national incentives for the effective protection of natural areas (Sekericioglu 2002; Nguyen et al. 2011). For example, vulture restaurants can be attractive sites for ecotourism, which supply additional food for vultures, raise public awareness, and provide critical funds for species conservation (BirdLife International 2021a, 2021b). Birds can also be attractive flagship species to increase audience for nature conservation (Verissimo et al. 2009). The traits influencing audience preference for the species include geographic distribution, population size, visibility, attractiveness, and keepability in human hands (Verissimo et al. 2014).

We found that 287 bird species native to Vietnam are migratory, falling at least in one of the categories wintering, breeding visitor or passage migrant. Due to their long and risky flyways, migratory bird species need specific conservation efforts across their whole range (Kirby et al. 2008; Larison et al. 2021). Conservation actions therefore require a strong cooperation between countries throughout the entire range of the species, including for example range wide counts, sharing of information on threats and conservation responses, and the protection of important sites for breeding, roosting, and wintering. The species-specific conservation measures for migratory birds can substantially change between wintering and breeding ranges. In breeding areas, establishing buffer zones around breeding colonies or sites, such as waterbird sanctuaries or vulture safe zones (BirdLife International 2020, 2021a, 2021b), can be useful tools. Furthermore, species-specific habitat management and conservation actions are needed. For the enigmatic Sarus Crane (VU) and Black-necked Crane (NT but extirpated in Vietnam), for example, further field surveys to identify important sites, habitat management and restoration actions such as stopping drainage of marshes or the creation of small wetland habitats, limiting the use of pesticides and rodenticides, involvement of the public in conservation activities, e.g., nest protection by private landowners and hobby ornithologists, raising public awareness, or rearing programs should be implemented immediately (BirdLife International 2016, 2020). Seasonal habitat management actions, such as leaving some harvested fields unploughed in the wintering grounds between November and March, or to control meadow livestock during key feeding periods from May to August, also need to be undertaken (BirdLife International 2020).

The Vietnam government is a signatory to the Convention on the Conservation of Migratory Species (CMS) and is a member of East Asian-Australasian Flyway Partnership (EAAFW), with a focus on the protection of migratory birds. Recently, the Vietnamese government has also strengthened conservation planning for wetland and waterbird. Specifically, Decree 66/2019/NĐ-CP issued in 2019 provide holistic principles for conservation and sustainable use of wetlands in the country. In 2021, Decision 1975/QĐ-TTg signed by the Prime Minister detailed the National Action Plan on conservation and sustainable use of wetlands for the 2021–2030 period. The priority has been set on the protection of existing endemic bird areas as well as important bird areas in Vietnam by re-evaluating and updating the status of those areas. It is necessary to add some new and important areas for bird conservation such as bird sanctuaries in the North-east and in the Mekong Delta which attracts thousands of breeding and wintering birds every year. Recently, the Biodiversity and Nature Conservation Agency of the Ministry of Agriculture and Environment proposed a list of 18 important wetland sites, comprising eight sites in the Red River Delta and northeastern region, three

sites in Central Coast and seven sites in southern Vietnam. Several RAMSAR sites in Vietnam play a key role for waterbirds, for example Xuan Thuy National Park (NP) in the North, Lang Sen Wetland Reserve, Can Gio Mangrove Biosphere Reserve, Cat Tien, Tram Chim, U Minh Thuong and Dat Mui NPs in the South.

Overall, raising awareness of local communities should be the first priority for bird conservation in Vietnam. In addition, strengthening the related bird protection laws and regulations, including an update of the government decree on bird protection, as well as strengthening the capacity and implementation of related authorities in the species protection and conservation such as forest rangers, environmental policies, staff of national parks and nature reserves in order to strictly control the habitat destruction, hunting, trapping and wildbird trade is necessary to effectively protect Vietnam's avifauna.

Vietnamese birds in zoos across ZIMS-regions

According to ZIMS and ZTL, 308 (18 in ZTL exclusively) Vietnamese bird species are kept in zoos, including only 21 (one in ZTL exclusively) threatened species. Furthermore, only two endemic and four near-endemic species are kept. Reasons might be that zoos prefer species for which husbandry knowledge exists, and species which are already held by other institutions, charismatic or colorful.

Some of the 750 ZIMS-institutions, which at least kept one of the 290 Vietnamese species listed in ZIMS, held several threatened and endemic species. For example, the Singapore Zoo held the most threatened Vietnamese bird species (eleven). Most (near-)endemic species were found at Saigon Zoo & Botanical Gardens, Ho Chi Minh City.

Only twelve of the 20 listed species in ZIMS were bred in the last twelve months, including *Lophura edwardsi* at 23 institutions. However, several threatened species were kept with <50 individuals, for example *Pseudibis davisoni* (nine), *Gyps bengalensis* (four), *Columba punicea* (three), *Pseudibis gigantea* (three), *Aceros nipalensis* (two), *Trochalopteron yersini* (two) and *Mulleripicus pulverulentus* (one). For these species, it should be discussed if ex situ efforts can be increased, for example by cooperating with local institutions or rescue centers. Alternatively, cooperation with institutions not registered in ZIMS or citizen conservation initiatives might be a source to increase the zoo stocks. Several small institutions such as rescue or breeding centers do not use ZIMS due to high licensing costs or low staff capacity. For example, the Vulture Conservation Breeding Centre, Pinjore, Haryana has been successfully keeping and breeding Asian Vulture species such as *G. bengalensis* and *G. tenuirostris*, which are likely extirpated in Vietnam (https://cza.nic.in/uploads/documents/reports/hindi/AR_vulturebrepinzore_2122.pdf). Ex situ zoo conservation can benefit from cooperation with in situ stations, as well as the latter from ex situ breeding successes in zoos, which is in the sense of the One Plan Approach, currently highlighted in the aforementioned Vietnamazing campaign

Combining in and ex situ conservation actions

The trapping for the cage bird trade has played a significant role in the Asian songbird crisis (Sykes 2017; Marshall et al. 2020). In recent years, conservation and ornithology experts have tackled the crisis through interdisciplinary research

and evidence-based strategies (Capotosto and Shepherd 2015; Shepherd and Chng 2017). Key initiatives include the 2016 Conservation Strategy for Southeast Asian Songbirds in Trade (Lee et al. 2016) and the establishment of the IUCN SSC Asian Songbird Trade Specialist Group (ASTSG) in 2017. The new approach emphasizes trade research to build robust datasets for guiding policies and conservation actions. For example, organizations like the Silent Forest Group and Monitor Conservation Research Society are developing databases such as the Songbirds in Trade Database (SiTDB; <https://www.sitdb.org/>) to track and analyze trade dynamics. A recent short-term study identified 50 species in the Vietnamese songbird trade, 46 of them native to Vietnam, and only nine species were protected by national law (Leupen et al. 2022). We also found significant mismatches between threatened species (43, 5.4%) according to the IUCN Red List, those evaluated in the VRDB (61, 7.6%) and those listed under the national decrees and international convention CITES (87, 10.8%). The most recent Vietnam Red List of Threatened Species (Nguyen 2024), which was published after our analyses, listed a total of 112 species of birds, comprising one species as EX, 24 species as CR, 44 species as EN and 43 species as VU (<http://vnredlist.vast.vn/>). Due to the critical threat to Asian songbirds, we recommend a more stringent national legislation on the whole order Passeriformes in Vietnam, as the protection of single threatened or highly traded species or genera might lead to a shift in species targeted for the cage bird trade. We further recommend the inclusion of additional threatened species of birds in the new governmental decree that is going to replace Decree No. 64/2019 and Decree No. 84/2021. The conservation campaign of the European Association of Zoos and Aquaria (EAZA) 2017–2019, “Silent Forest – Asian Songbird Crisis”, has also tackled songbird decline by informing the public and collecting funds for improved conservation measures.

Vietnam has already lost some of its native bird species such as the Black-necked Crane (*Grus nigricollis*) (NT), the Chinese Grassbird (*Graminicola striatus*) (NT) and the Giant Ibis (*Pseudibis gigantea*) (CR), which are now extirpated nationally (Le et al. 2021; IUCN 2025). In addition, two vulture species, *Gyps tenuirostris* and *G. bengalensis*, both CR and possibly extinct in Vietnam as well as the endemic Edwards Pheasant (*Lophura edwardsi*), which is very likely extinct in the wild (Eames and Mahood 2017). For these highly threatened or lost species, conservation breeding or rewilding measures based on species-specific knowledge can be effective (Conde et al. 2013; Schwartz et al. 2017).

The Edwards Pheasant, which is listed as CR with a decreasing population trend according to the IUCN Red List, has not been reported from its natural habitat, central Vietnam’s lowland evergreen forest, since the year 2000, despite subsequent intensive research, and it may already be extinct in the wild. Habitat loss and degradation, as well as hunting are the two primary drivers for its possible extinction. Together with rewilding, for example, the preparation of a landscape level management plan to enhance connectivity among sites, the assessment and control of hunting, and public awareness campaigns are recommended (BirdLife International 2024). Furthermore, two additional proposed reserves, the Phong Dien and Dakrong Nature Reserves, have been established and Dong Chau-Khe Nuoc Trong Nature Reserve has been set aside to protect the species. VietNature is currently operating a conservation breeding program in the PA with a view releasing held individuals back to the wild. The EAZA Vietnamizing campaign 2024–2025 thus will promote for the flagship species Vietnam Pheasant

(Ziegler et al. 2024): raising awareness of this pheasant species and its threats; the set-up and management of further breeding facilities in Vietnam in order to be prepared for future reintroductions; field research in potentially suitable and protected forest sites for subsequent releases; involvement of local residents to ensure their long-term survival; genetic analyses by EAZA Biobank to identify and remove possible hybrids from the breeding programme and provide recommendations on pairing/release; introduction of an action plan.

The species recently also was included in the updated Vietnam Red Data Book (Nguyen 2024), listed as protected species in the Circular No. 27/2025/BNMT of the Ministry of Agriculture and Environment. In addition, in the Decision 49/QĐ-TTg of the Prime Minister, viz. the National Program for Species of Conservation Priority 2025–2030, the four tasks research, in situ conservation, conservation breeding and re-introduction, as well as the development of conservation action planning was highlighted, and in Decision No. 1352/2024/QĐ-TTg by the Prime Minister, amongst others Hanoi Zoo, which has been keeping and breeding the species, was listed as a Conservation facility of Vietnam. Another example are the likely nationally extirpated White-rumped Vulture and Slender-billed Vulture, but also vulture species in general, their primary threats derive from the use of diclophenac and other drugs (BirdLife International 2021a, 2021b). Countries like India, Nepal, Pakistan and Bangladesh already banned the veterinary use of diclophenac, marked human diclophenac containers “not for veterinary use”, and India even stopped the production of diclophenac in vial sizes larger than 3 ml (the single dose for humans), which made the use for veterinary purposes too complicated and expensive. Additionally, diclophenac is already partially exchanged with the vulture-safe drug meloxicam, which led to a reduction of diclophenac in ungulate carcasses (BirdLife International 2021a, 2021b). Combining these *in situ* actions with conservation breeding efforts from the global zoo community, resulting in future rewilding, similarly to the Edward’s Pheasant, may be a useful measure to establish the two species in Vietnam again.

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Additional information

Conflict of interest

The authors have declared that no competing interests exist.

Ethical statement

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Use of AI

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Author contributions

Conceptualization: DR, TZ. Data curation: TQN, MDL, HML. Formal analysis: HH, DR. Methodology: DR, MDL, HMLM. Project administration: DR, TZ. Supervision: DR, TZ. Writing - original draft: TZ, PG, MDL, HH. Writing - review and editing: DR, TZ, MDL, HH, TQN, PG.

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Data availability

All of the data that support the findings of this study are available in the main text or Supplementary Information.

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Supplementary material 1

Suppl. table S1

Authors: Philipp Ginal, Helena Hackenbroch, Hung Le Manh, Truong Quang Nguyen, Minh Duc Le, Dennis Rödder, Thomas Ziegler

Data type: csv

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Supplementary material 2

Suppl. tables S2–S7

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Data type: doc

Explanation note: **table S2:** Exclusions of bird species listed by Le et al. (2020). **table S3:** Species and their IUCN Red List status, listed in the Vietnam Red Data Book, Decree No. 64/2019, Decree No. 84/2021 or in CITES. **table S4:** Species listed in Decree No. 84/2021 and the Vietnam Red Data Book, which are not in our final species list of this thesis and the given reason. **table S5:** Bird species kept according to ZIMS, including their IUCN Red List status, the number of institutions and regions, number of individuals and births within the last twelve months. **table S6:** Species only held according to ZTL, their IUCN Red List status and number of zoos. **table S7:** Zoological institutions keeping at least two threatened Vietnamese bird species (according to ZIMS).

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